(19) Europäisches Patentamt
European Pat nt Office
Offic uropéen d s brevets

(11) EP 0 479 085 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
16.04.1997 Bulletin 1997/16

(51) Int Cl.[6]: **G02B 5/18**, G02F 1/01, G02B 26/08

(21) Application number: **91116125.5**

(22) Date of filing: **23.09.1991**

(54) Tunable diffraction grating

Abstimmbares Beugungsgitter

Réseau de diffraction accordable

(84) Designated Contracting States:
DE FR GB

(30) Priority: **03.10.1990 US 592389**

(43) Date of publication of application:
08.04.1992 Bulletin 1992/15

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(56) References cited:
DE-A- 3 943 387 **DE-A- 4 119 847**

- **ELECTRONICS AND COMMUNICATIONS IN JAPAN vol. 63-C, no. 10, 1980, NEW YORK US pages 94 - 100 T.UTSUNOMIYA AND H.SATO 'electrically deformable echelette grating and its application to tunable laser resonator'**

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Printed by Jouve, 75001 PARIS (FR)

D scription

Field of the Invention

This invention relates, in general, to a diffraction grating, and more particularly, to a tunable diffraction grating.

Background of the Invention

Information may be transmitted through optical wavelengths in the visible and near visible region. The amount of information which may be transmitted through optical wavelengths may be increased by multiplexing several beams of light, each of a different wavelength and modulated such that each alone is transmitting a large amount of information.

These wavelengths of light, are usually transmitted through an optical fiber. Each individual wavelength of light then must be separated in order to receive and process the information transmitted on it. A diffraction grating is suitable for this purpose. Semiconductor devices, such as photodetectors, are used to further process the wavelength of light.

A diffraction grating of the prior art consists of a glass, quartz, or plastic material having peaks and valleys or rows having a fixed spacing. The material is transparent at the wavelength of interest. An optical fiber is positioned such that the light traverses the diffraction grating. The spacing between the rows or the valleys between the peaks are positioned such that the wavelength of interest is diffracted along the grating. This means that the spacing or width of the valleys must be fixed along a predetermined section of the grating. The spacing or width of the valleys can be different in different sections of the diffraction grating such that different wavelengths of light diffract at different sections along the grating. Each of the wavelengths may then be further processed at particular locations along the diffraction grating.

If these diffraction gratings are integrated along with semiconductor integrated circuits, it is desirable for the diffraction grating to be easily integratable and for it to be as small as possible. In order to monitor a large amount of information, either multiple diffraction gratings having fixed spacing or a large grating having variable spacing is necessary. It is also necessary to have multiple photodetectors, one for each grating or one for each wavelength of light to be monitored along a grating having variable spacing. It is desirable to be able to monitor large amounts of information on one small diffraction grating.

Another method of separating wavelengths of light is with the use of Fabri-Perrot interferometers with piezoelectric drives. Th disadvantage of these structures is that they are complicated, delicate, and expensive.

DE-A-3 943 387 describes a diffraction grating having an inactive grating body and a piezo-electrically active grating support, which allows fine tuning of the wavelength of diffracted radiation.

Electronics and communications in Japan, vol. 63-C, no.10, pages 94-100, by T. Utsunomiya et al, entitled "Electrically Deformable Echelett Grating and Its Application to Tunable Laser Resonator", describes an electrically deformable Echelette grating with diffraction characteristics controlled by shear strain of a piezoelectric material.

Summary of the Invention

In accordance with the invention there is provided a tunable diffraction grating, comprising: elements of an electrically conductive material disposed on a deformable material in a row, wherein the deformable material is transparent to a number of wavelengths of light and is deformable in accordance with an applied electrical field, and wherein the elements of the electricallv conductive material diffract a first wavelength of light; and a means for applying a voltage on the elements of the electrically conductive material to cause a change in spacings between the elements so that the diffraction grating diffracts a second wavelength of light.

Brief Description of the Drawings

FIG. 1 illustrates an enlarged, top view of a portion of a diffraction grating of the present invention;
FIG. 2 illustrates an enlarged, cross-sectional view of a first embodiment of the present invention;
FIG. 3 illustrates an enlarged, cross-sectional view of a second embodiment of the present invention;
FIG. 4 illustrates a top view of a portion of a diffraction grating of the present invention, shown in a first configuration;
FIG. 5 illustrates a top view of a diffraction grating of the present invention, shown in a second configuration; and
FIG. 6 illustrates a top view of a diffraction grating of the present invention, shown in a third configuration.

Detailed Description of the Drawings

FIG. 1 illustrates an enlarged, top view of a portion of a diffraction grating 10 of the present invention. What is shown is alternate rows of elements 12 and 14 of an electrically conductive material disposed on a deformable material 11. Rows 12 are spaced apart from rows 14 by a spacing 16. The distance between a row 14 starting from a point closest to a row 12 to the outside edge of that row 12 is shown here as spacing 17. The wavelength of a light 19 which will be selected by a particular diffraction grating 10, for a given angle of incidence and diffraction, is a function of spacing 17. Spacing 16 is shown for convenience in d scribing tunable diffraction grating 10 of the present invention. Note also that the

wavelength of light 19 which will be selected is also a function of sDacina 16 because spacing 16 is a function of spacing 17. To select one wavelength of light 19, spacing 16 must be substantially the same between rows 12 and 14 in a given portion of grating 10 along a path in which incident light 19 traverses. The length of the portion in which spacing 16 must be substantially the same is dependent upon the percentage of the wavelength of light 19 which is to be selected which is necessary to transmit information. Note that grating 10 may be divided into several portions (not shown) having spacing 16 of a different width, but the same in each specific portion.

Any electrically conductive material may be used to form rows 12 and 14. Examples of such materials include gold or polyacetylene. Deformable material 11 must be optically transparent to the wavelengths of light 19 which are to be selected. Any deformable materials, such as polymers or elastomers having an index of refraction n_1, may be used.

Diffraction grating 10 can be tuned by applying a positive voltage on rows 12 and 14, by applying a negative voltage on rows 12 and 14, or by applying a negative voltage on rows 12 and a positive voltage on rows 14 (or vice versa) by any suitable means. When the voltage is applied to rows 12 and 14, the electrostatic forces between rows 12 and 14 cause each alternate row 12 and 14 to repel or attract each other thus increasing or decreasing spacing 16.

FIG. 2 illustrates a cross-sectional view of a portion of diffraction grating 10 as shown in FIG. 1, but having a new spacing 16'. FIG. 2 illustrates the case where a negative voltage 20 is applied to rows 12 and rows 14. When negative voltage 20 is applied to rows 12 and 14, the electrostatic forces between rows 12 and 14 cause each alternate row 12 and 14 to repel each other thus increasing spacing 16 to a new spacing 16'. New spacing 16' diffracts a different wavelength of light than spacing 16. Varying the voltage on rows 12 and 14 changes spacing 16, so that by proper design of rows 12 and 14 and spacing 16, diffraction grating 10 may be used to tune across a band of wavelengths of light 19 for the desired wavelength. Upon varying the voltage on rows 12 and 14, rows 12 and 14 are able to move because they are positioned on deformable material 11. Diffraction grating 10 may also be used to minimize noise by tuning by selecting only the desired wavelengths of light.

Rows 12 and 14 of diffraction grating 10 may be fabricated on deformable material 11 by any suitable methods known in the art. For example, rows 12 and 14 may be fabricated by casting them on deformable material 11. Rows 12 and 14 may also be formed by sputtering or evaporating an electrically conductive material on deformable material 11 and then removing portions of the lectrically conductive material to form rows 12 and 14. Removal of portions of th el ctrically conductive material may be accomplished by, for example, etching or ion milling.

FIG. 3 illustrates a cross-sectional view of a second embodiment of a diffraction grating 10 of the present invention. The same reference numerals are used for the same elements shown in FIG. 1 throughout all the FIGs. In this embodiment, a s cond deformable material 30 is formed over rows 12 and 14. Deformable material 30 may be the same as deformable material 11, having the same index of refraction n_1. However, it may be desirable for deformable material 30 to have a second index of refraction n_2. In this case, deformable material 11 would work to further bend a particular wavelength of light 19 into, for example, a photodetector 25. Diffraction grating 10 is positioned on photodetector 25 by any suitable means. In fact, diffraction grating 10 may be separated from photodetector 25 by a pocket of air (not shown). Preferably, diffraction grating 10 is integrated with photodetector 25 or other devices that are capable of manipulating light.

FIG. 4 illustrates a top view of a diffraction grating 10 formed in a first configuration. As described with reference to FIG. 1, spacing 16 must be substantially the same in a given portion of diffraction grating 10 along a path through which incident light 19 traverses. Thus, spacing 16 outside the path in which incident light 19 traverses may vary in a given portion of diffraction grating 10. This means that an infinite number of configurations are possible as long as spacing 16 is the same in a given portion of diffraction grating 10 along the path in which incident light 19 traverses. FIG. 4 illustrates one such configuration. Note that rows 12 are conveniently connected so that a means for applying a positive voltage 21 is also convenient. Rows 14 are formed in similar fashion, but have negative voltage 20 applied thereto. In this embodiment, when positive voltage 21 and negative voltage 20 is applied, rows 12 and 14 would attract each other, thus providing decreased spacing 16'.

FIG. 5 illustrates a second configuration of a diffraction grating 10. In this embodiment, when positive voltage 21 is applied, rows 12 and 14 would repel each other, thus providing increased spacing 16'. Rows 12 and 14 of diffraction grating 10 must be designed to take into account the stresses, resistances, and capacitances present in diffraction grating 10. These parameters depend on the materials which comprise rows 12 and 14 and deformable layer 11. What is desired is that rows 12 and 14 be designed such that when positive voltage 21 is applied, new spacing 16' is still the same between rows 12 and 14 for a given section of diffraction grating 10. FIG. 5 illustrates a diffraction grating 10 having rows 12 and 14 having a diminishing length along a portion of diffraction grating 10. This configuration may be preferable where there is low resistance and capacitance present.

FIG. 6 illustrates a third configuration of diffraction grating 10. In addition, note that spacing 16 along th path in which incident light 19 traverses diffraction grating 10 can be designed to be substantially the sam . Many other configurations, obviously which all can not

be shown, are possible.

As can be readily seen, a tunable diffraction grating has been provided by the present invention. Th tunabl diffraction grating of the present invention allows selection of different wavel ngths of light by varying th voltage across alternate rows of a diffraction grating. In this manner, large amounts of information may be transmitted and received in a small, integrable tunable diffraction grating.

Claims

1. A tunable diffraction grating (10), comprising:

   elements (12, 14) of an electrically conductive material disposed on a first deformable material (11) in a row, wherein the deformable material (11) is transparent to a number of of wavelengths of light (19) and is deformable in accordance with an applied electrical field, and wherein the elements (12, 14) of the electrically conductive material diffract a first wavelength of light (19); and

   a means for applying a voltage (20, 21) on the elements (12, 14) of the electrically conductive material to cause a change in spacings (16, 17) between the elements (12, 14) so that the diffraction grating (10) diffracts a second wavelength of light (19).

2. The tunable diffraction grating of claim 1 wherein the electrically conductive material is a reflective or transmissive material.

3. The tunable diffraction grating of claim 1 further comprising a photodetector (25) adjacent to the tunable diffraction grating (10).

4. The tunable diffraction grating of claim 1, wherein the means for applying a voltage (20,21) comprises a means for applying a positive (21) and a negative (20) voltage on alternate elements (12, 14) of the electrically conductive material.

5. A tunable diffraction grating as claimed in claim 1 including;

   a second deformable material (30) disposed on the elements (12, 14) of the electrically conductive material, wherein the second deformable material (30) is transparent to a light (19) of numerous wavelengths and has an index of refraction (n2) different from the index of refraction (n1) of the first deformable mat rial.

6. A grating as claimed in claim 1, wherein the elements (12, 14) comprise first (12) and second (14) rows of elements, the elements (12, 14) of each row having a predetermined spacing (17) and the ends of the elements (12, 14) being inter-digitated to provide a second spacing (16) between adjacent edg s of lements (12, 14).

7. A grating as claimed in claim 6, wherein the ends of the elements (12, 14) of each row remote from the inter-digitated ends are coupled by a common respective power bus.

8. A grating as claimed in claims 6 or 7, wherein the length of the individual elements (12, 14) decreases in a direction along the rows.

9. A grating as claimed in claim 1, wherein the elements (12, 14) are arcuate and concentric in configuration and wherein a cross-section of the arcuate and concentric configuration forms the row of elements (12, 14).

Patentansprüche

1. Abstimmbares Brechungsgitter (10), das umfaßt:

   Elemente (12, 14) eines elektrisch leitenden Materials, die auf einem ersten verformbaren Material (11) in einer Reihe angeordnet sind, wobei das verformbare Material (11) für eine Reihe von Wellenlängen von Licht (19) durchlässig und entsprechend einem angelegten elektrischen Feld verformbar ist, wobei die Elemente (12, 14) des elektrischen leitenden Materials eine erste Wellenlänge von Licht (19) brechen; sowie

   eine Einrichtung zum Anlegen einer Spannung (20, 21) an die Elemente (12, 14) des elektrisch leitenden Materials, so daß sich die Zwischenräume (16, 17) zwischen den Elementen (12, 14) ändem und das Brechungsgitter (10) eine zweite Wellenlänge von Licht (19) bricht.

2. Abstimmbares Brechungsgitter nach Anspruch 1, wobei es sich bei dem elektrisch leitenden Material um ein reflektierendes oder durchlässiges Material handelt.

3. Abstimmbares Brechungsgitter nach Anspruch 1, das des weiteren einen Photodetektor (20) an das abstimmbare Brechungsgitter (10) angrenzend umfaßt.

4. Abstimmbares Brechungsgitter nach Anspruch 1, wobei di Einrichtung zum Anl gen einer Spannung (20, 21) eine Einrichtung zum Anlegen einer positiv n (21) und einer n gativen (20) Spannung an al-

ternierende Elemente (12, 14) des elektrisch leitenden Materials umfaßt.

5. Abstimmbares Brechungsgitter nach Anspruch 1, das enthält:
ein zweites verformbares Material (30), das auf den Elementen (12, 14) des elektrisch leitenden Materials angeordnet ist, wobei das zweite verformbare Material (30) für ein Licht (19) mehrerer Wellenlängen durchlässig ist und einen Brechungsindex (n_2) hat, der sich vom Brechungsindex (n_1) des ersten verformbaren Materials unterscheidet.

6. Gitter nach Anspruch 1, wobei die Elemente (12, 14) eine erste (12) und eine zweite (14) Reihe von Elementen umfassen, wobei die Elemente (12, 14) jeder Reihe einen vorgegebenen Zwischenraum (17) haben und die Enden der Elemente (12, 14) fingerartig ineinandergreifen, so daß ein zweiter Zwischenraum (16) zwischen benachbarten Rändern von Elementen (12, 14) entsteht.

7. Gitter nach Anspruch 6, wobei die Enden der Elemente (12, 14) jeder Reihe, die von den fingerartig ineinandergreifenden Enden entfernt sind, durch eine gemeinsame entsprechende Potentialschiene verbunden sind.

8. Gitter nach Anspruch 6 oder 7, wobei die Länge der einzelnen Elemente (12, 14) in einer Richtung entlang der Reihen abnimmt.

9. Gitter nach Anspruch 1, wobei die Elemente (12, 14) bogenförmig und konzentrisch aufgebaut sind und wobei ein Querschnitt des bogenförmigen und konzentrischen Aufbaus die Reihe von Elementen (12, 14) bildet.

Revendications

1. Réseau de diffraction accordable (10), comprenant :

des éléments (12, 14) faits d'une matière conductrice de l'électricité, disposés en une rangée sur une première matière déformable (11), dans lequel la matière déformable (11) est transparente pour un certain nombre de longueurs d'onde de lumière (19) et est déformable en fonction d'un champ électrique appliqué, et dans lequel les éléments (12, 14) de la matière conductrice de l'électricité diffractent une première longueur d'onde de lumière (19) ; et
un moyen pour appliquer une tension (20, 21) aux éléments (12, 14) faits de la matière conductrice d l'électricité pour provoquer un variation des écartements (16, 17) entr les éléments (12, 14) d sorte qu l réseau de diffraction (10) diffracte une d uxième longueur d'onde de lumière (19).

2. Réseau d diffraction accordable s lon la revendication 1, dans lequel la matière conductrice de l'électricité est une matière réfléchissante ou transmissive.

3. Réseau de diffraction accordable selon la revendication 1, comprenant en outre un photodétecteur (25) adjacent au réseau de diffraction accordable (10).

4. Réseau de diffraction accordable selon la revendication 1, dans lequel le moyen pour appliquer une tension (20, 21) comprend un moyen pour appliquer une tension positive (21) et une tension négative (20) aux éléments alternés (12, 14) faits de la matière conductrice de l'électricité.

5. Réseau de diffraction accordable selon la revendication 1, comprenant :

une seconde matière déformable (30) disposée sur les éléments (12, 14) faits de la matière conductrice de l'électricité, dans lequel le second moyen déformable (30) est transparent pour une lumière (19) de nombreuses longueurs d'onde et a un indice de réfraction (n_2) différent de l'indice de réfraction (n_1) de la première matière déformable.

6. Réseau selon la revendication 1, dans lequel les éléments (12, 14) comprennent des premières rangées (12) et secondes rangées (14) d'éléments, les éléments (12, 14) de chaque rangée ayant un écartement prédéterminé (17) et les extrémités des éléments (12, 14) étant interdigitées pour créer un second écartement (16) entre les bords adjacents des éléments (12, 14).

7. Réseau selon la revendication 6, dans lequel les extrémités des éléments (12, 14) de chaque rangée, éloignées des extrémités interdigitées, sont reliées par un bus d'alimentation respectif commun.

8. Réseau selon les revendications 6 ou 7, dans lequel la longueur des éléments individuels (12, 14) diminue dans le sens de la longueur des rangées.

9. Réseau selon la revendication 1, dans lequel les éléments (12, 14) sont disposés en arcs concentriques, et dans lequel une section transversale de la disposition en arcs concentriques forme la rangée d'éléments (12, 14).

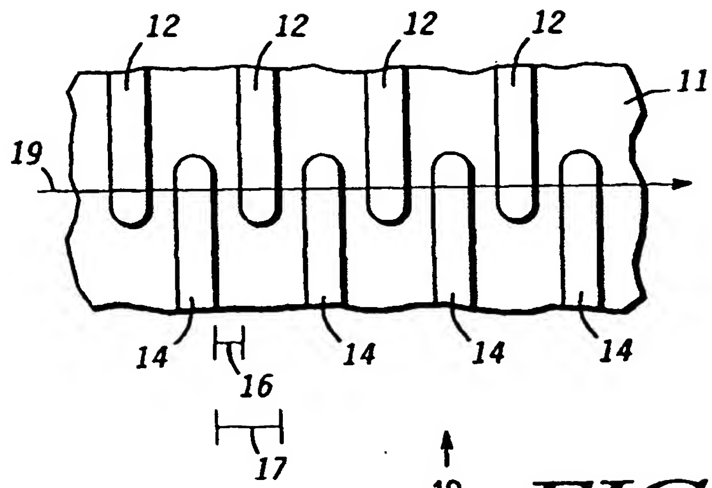


FIG. 1

FIG. 2

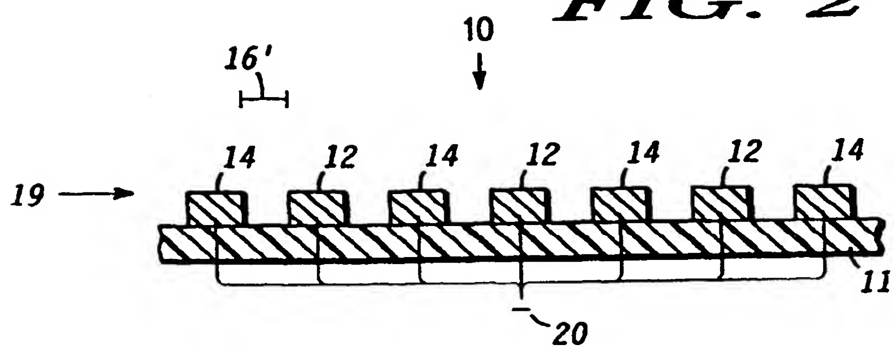
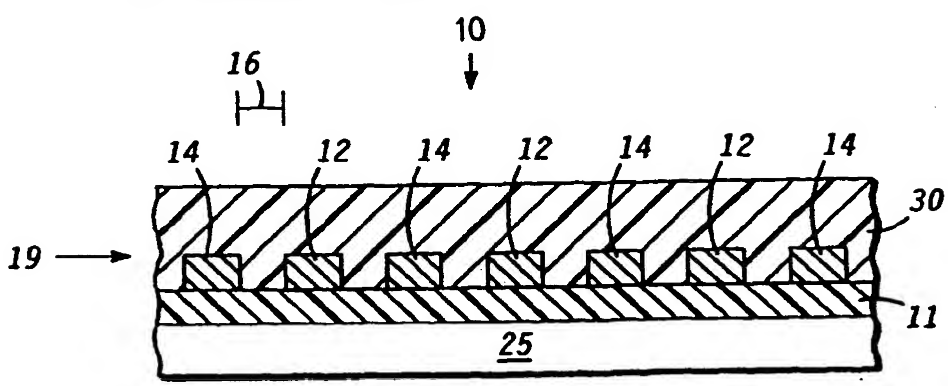


FIG. 3



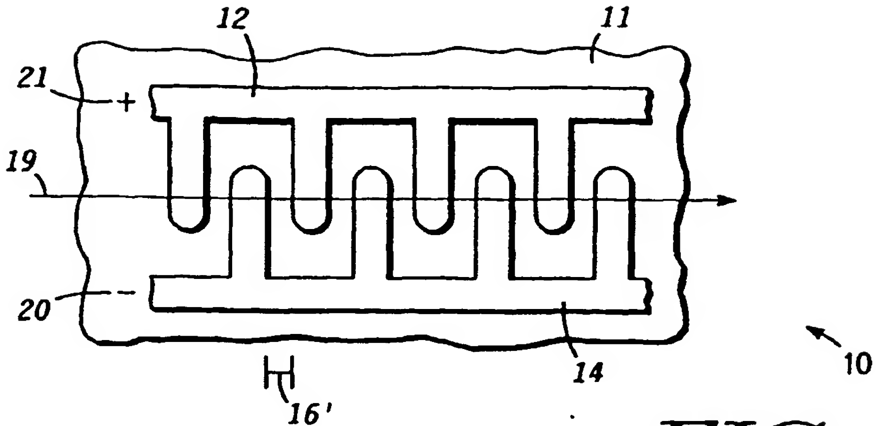
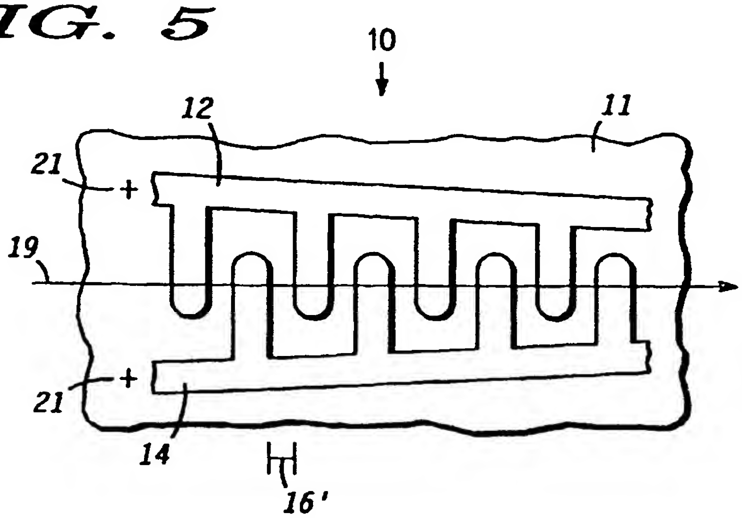


FIG. 4

FIG. 5



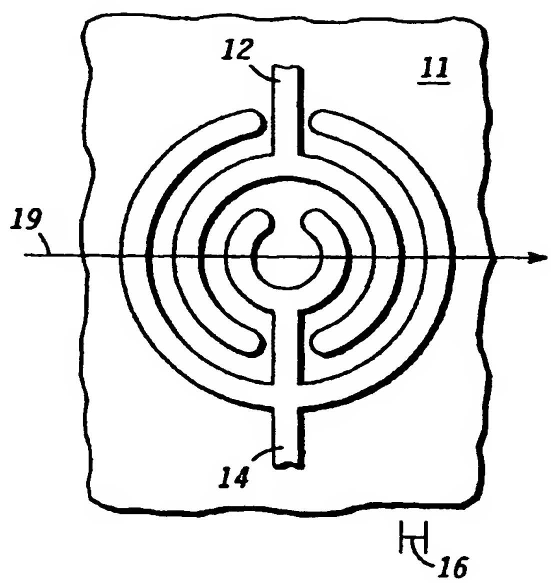


FIG. 6